A Coherent, High Resolution Processor to Localize and Track Acoustic Sources

Claire Debever
Marine Physical Laboratory
Scripps Institution of oceanography
La Jolla, CA 92093-0238
phone: (858) 534-9853 fax: (858) 534-7641 email : cdebever@ucsd.edu

Grant Number: N00014-06-1-0198

LONG-TERM GOALS

Localizing a source using matching-field processing requires enough array elements to have an adequate array gain and a very good knowledge of the oceanic environment. It often is complicated by the presence of loud, fast-moving interferers, and the source itself being non-stationary. Our goal is to develop a robust matched-field processing technique well suited for practical applications in challenging environments.

OBJECTIVES

Matched-field processing (MFP) is based on the comparison between the recorded acoustic data and the synthetic one issued from a source at a hypothetical position, an environmental model of the waveguide and a propagation code. When the source signal is weak, and/or propagates in a noisy waveguide, using an array of sensors to coherently add the signal received at each element is essential to distinguish the signal from the noise. Hence an important area of research, and one of our main objectives, is to improve the signal detectability at the output of the array by increasing the array gain.

APPROACH

Since a large number of array elements is desirable to better detect the source signal imbedded in noise, but larger arrays are less practical than shorter ones, an interesting solution is to use multiple short arrays recording the source signal from different locations in the waveguide. The received data is then typically processed incoherently between arrays to yield an estimate of the source position. Such a process however neglects an important part of the signal: the coherent contributions between receivers from different sub-arrays. This coherent summation of the signal between sensors is essential to enhancing the signal power over noise at the output of the processor. Therefore a coherent inter-array processing of the data is expected to give a more accurate source localization result, providing that the distance between individual arrays is small enough that the inter-array signal remains coherent. Furthermore, another way to increase the gain at the output of the array is to use additional frequencies coherently, i.e. implement a coherent broadband processor, instead of using additional array elements. These extra-frequencies essentially increase the size of the cross-spectral density matrix, exactly as if more array elements were involved in the processing. Therefore, we propose to investigate the performance of a coherent broadband, coherent inter-array conventional matched-field processor in a shallow water environment.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2008	**Annual**	**00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE
A Coherent, High Resolution Processor To Localize And Track Acoustic Sources

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Scripps Institution of oceanography,Marine Physical Laboratory,La Jolla,CA,92093-0238

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT
Localizing a source using matching-field processing requires enough array elements to have an adequate array gain and a very good knowledge of the oceanic environment. It often is complicated by the presence of loud, fast-moving interferers, and the source itself being non-stationary. Our goal is to develop a robust matched-field processing technique well suited for practical applications in challenging environments.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**5**	

WORK COMPLETED

The SWellEx-96 experiment was chosen to test our algorithm. It took place in shallow water (200 m) out of Point-Loma, San-Diego. An acoustic source was towed at 9 m deep over an essentially flat bottom, and the acoustic field was sampled by two 27-element horizontal line array.

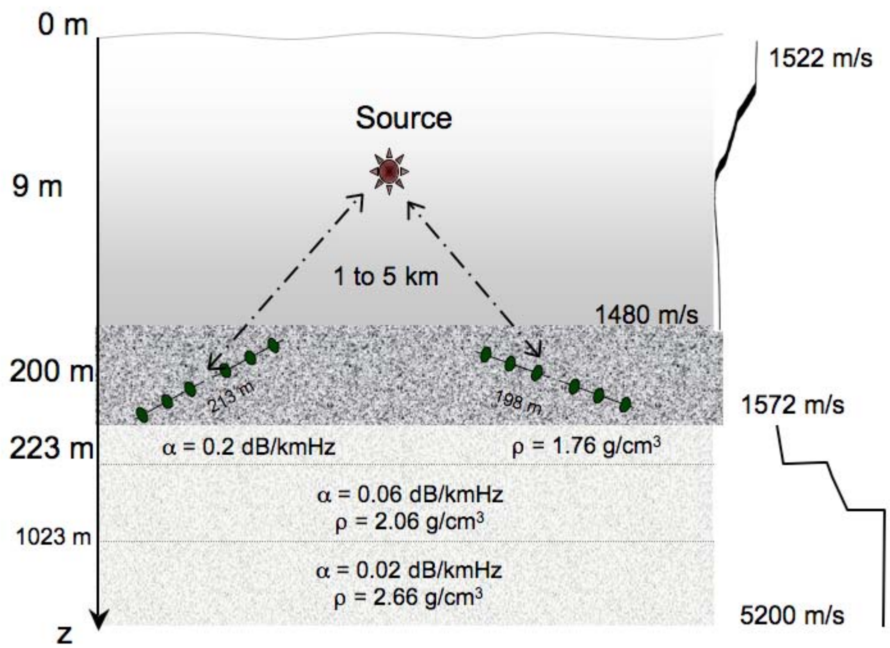

Figure 1. The SwellEX-96 environment model used to create the replica vectors

The two arrays were approximately 3 km away, and the source traveled from 3 km to 800 m away from the North array and 500 m to 3.3 km away from the South array. Data from twenty-five source positions are provided, with an average SNR at each element of 6 to 12 dB. The source sent nine multitones between 110 and 400 Hz.

RESULTS

Since the point of the processor is to coherently treat the signal between individual arrays, one of the first steps of the method is to assess how much coherence, if any, we can actually expect from signals received at such distant locations. Indeed the distance between the arrays is 200 to 800 times larger than the signal wavelength at such frequencies. A comparison between the dynamic ranges obtained from ambiguity surfaces for every combination of incoherent or coherent processing between arrays and frequencies (Fig.3) shows that the method indeed yields a coherent gain of about 0.9 dB when using inter-array contributions coherently, and an additional 3.3 dB when processing frequencies coherently.

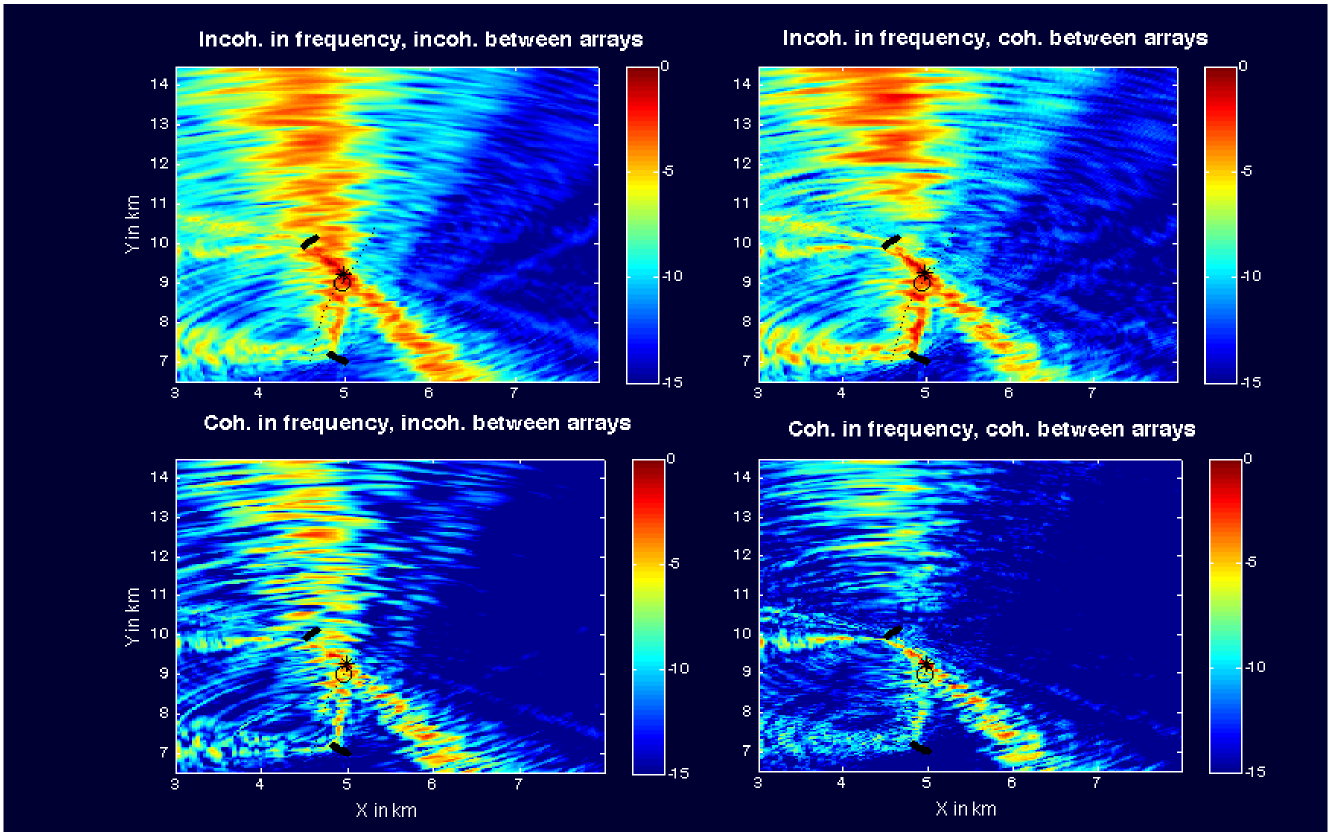

Figure 2. Example of source localization. The arrays are represented by the two black lines, the true source position by the black circle, and the found source position by the black star.

The next step was to study the tracking capability of the algorithm. The results showed that the source was tracked in the region broadside from both arrays, but not when endfire from one or the other (Fig.4 and 5). The red oval shows the region broadside from the arrays.

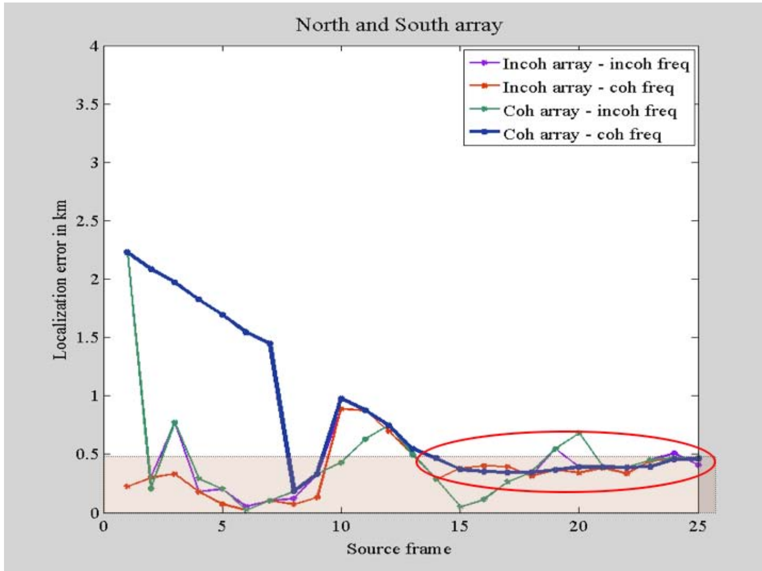

Figure 3. Error in the source position for each processor.

Fig.3 shows that the while the source is localized broadside from the arrays, there seems to be a consistent bias of a couple hundred meters between the true and found source tracks. This discrepancy could come from erroneous array's location. In an effort to improve the accuracy of the results, a self-focusing method, simulated annealing is used to get an estimate of the array's position from the data. A shift of the North array 56 m west, 300 m south, and a shift of the South array 14 m east, 80 m south minimized the simulated annealing cost function, and gave the best match between the true source track and the estimated one. The new array positions in brown, and source track associated with it are displayed in Fig.4.

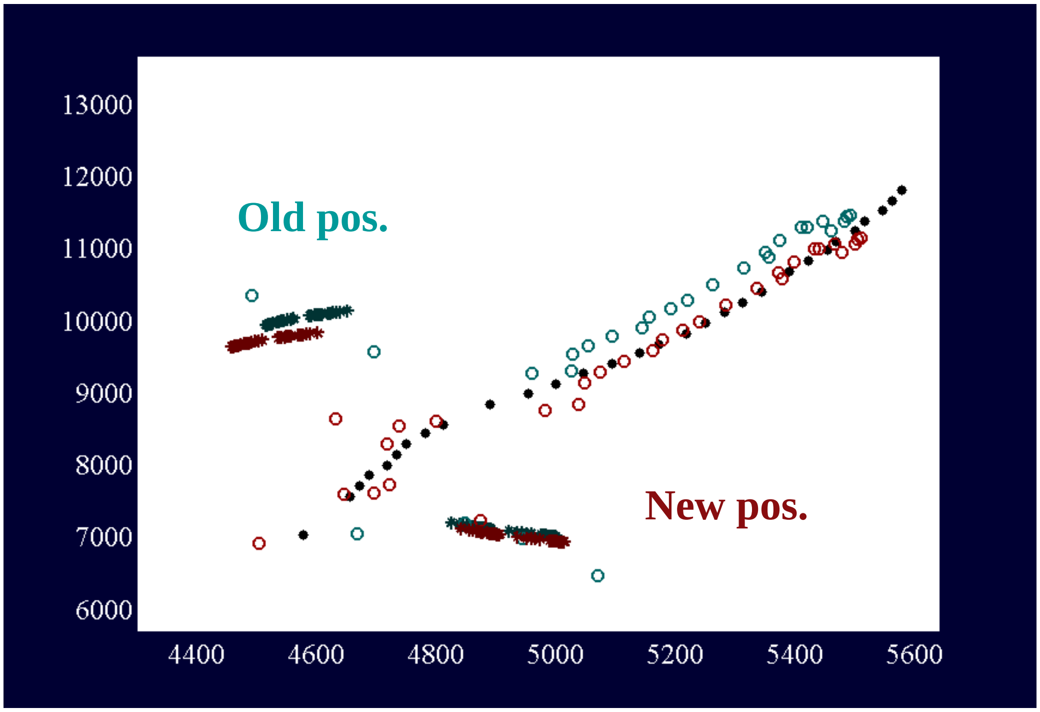

Figure 4. Source track from the new array positions (brown).

IMPACT/APPLICATIONS

Improving the robustness and detectability of sound sources in the ocean without sacrificing resolution has implications for monitoring of marine life and human vessels. Robustness is particularly important in continental shelf regions where the sound interaction with the surroundings is complicated, and can’t be described accurately.

RELATED PROJECTS

PlusNET

PUBLICATIONS

Claire Debever and W. A. Kuperman, “Robust matched-field processing using a coherent broadband white noise constraint processor”, J. Acoust. Soc. Am. **122** (4), October 2007 [published].